Image Enhancement - Revised Outline

PHOTOCHROMIC IMAGE PROCESSING

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I. PHOTOCHROMIC COATINGS

A. Immediate visibility (no development).
B. Reversible (prints a transparency either as a positive or a negative).
C. High resolution and grain free.
D. Ease of handling (no special precautions required).
E. Colored state optimum for humans.
F. Writing produced by exposure to near UV.
G. Erasing achieved with green light after pre-coloring with near UV.
H. Filter (colored) contrast control by changing viewing filters (e.g. green - maximum contrast, orange -- medium contrast, red - no contrast).
I. Low sensitivity, thus must be used with light sources and optical systems compatible with sensitivity. They cannot be put in cameras for taking pictures (similar to Kalvar film products in sensitivity).

J. Useful life of approximately 1,000 UV exposures.

II. APPLICATION TO THE PHOTOGRAPHIC DARKROOM USING STANDARD EQUIPMENT

A. Photochromic masking - provides a means for making either a positive or negative mask of the original transparency: can be contact or projection printed to a green sensitive emulsion.

1. Contrast suppression - a positive is made of the negative (in register with it) by passing UV light through the negative prior to printing. The sandwich is then used as the printing transparency.

2. Contrast enhancement - here the photochromic coating is colored by UV prior to forming the sandwich with the photographic negative and the image is formed as a negative by erasing illumination. The combination is then printed.

3. Edge enhancement - this can be accomplished by placing different spacers in the sandwich and/or controlling the specularity of the illumination.

B. Photochromic Reversible Print Paper

1. Sensitize by heat (½ hour).
2. Color by UV and erase with green.
3. Fix by heat.
4. Sensitive for ½ hour.
5. Uncolored regions can be resensitized and colored by a repetition of the process.

III. IMAGE PROCESSING BY PHOTO-INTERPRETERS

A. Present operational equipment - today this is primarily electronic image processing through television techniques. This provides:

1. Brightness control
2. Contrast control
   a. Enhancement
   b. Compression
   c. Slicing and expansion
3. Signal processing through filtering, delay and shaping to optimize the system transfer function for particular operations.
4. Operations can be controlled by the operator (dynamic control).
5. By application of computers complex analysis can be performed rapidly.
6. Costly equipment.
7. Reduced lines per field as compared to optical resolution.
8. Scanning problems exist for optimum results.

B. Desireable Objective - Optical Analog of the TV Image Processor

1. Optical communication theory leads to same transfer function approach to optical systems as is used for electronic systems and analogous image processing (for linear systems).
2. Some effects are very simple to obtain by spatial operations within optical systems.
3. In past, effects were principally used in phase contrast microscopy and Schleirin optical systems, but analytical techniques have been much more cumbersome than those used in electronics.
4. Fairly simple to apply results of research in electrical filter theory to predict resultant imagery by analogous techniques in the optical case.
5. System is amenable to mathematical analysis and includes present capabilities in general. Can determine what user does to get best image for a given situation.
6. User can develop a feel for spatial filtering.
7. Compatible for both manual and automatic image evaluation and manipulation.

C. Processing with Non - Coherent Optical Viewers

1. Low pass filtering by aperture control possible.
   a. Grain and fine detail can be minimized by stopping down.
      1. Projection lens - brightness loss occurs by reducing aperture.
      2. Eyeball (pinhole) - internal feedback tends to overcome brightness loss.
   b. One dimensional filtering can give some very interesting effects. A slit near the eyeball is quite effective.

c. Slits in colored transparency also of interest, but attention must be paid to intensity level.

2. Unsharp positive - negative masking (dodging)
   a. Use of a dodging mask in the viewer allows variable masking effects
      1. Variable distance between mask and original (defocus of mask)
      2. Relief by misregistration.
   b. Use of flicker effects to emphasize detail by rapidly varying defocus and misregistration in 2a.
   c. Can relay image of mask into object transparency and smear this image to give controlled edge enhancement.
3. Multiple image production
   a. An optical viewer can be considered an infinite number of projectors in parallel all focusing simultaneously on the screen (with the identical transparency as an input).
   b. Analysis of what can be done then is simple as it amounts to considering what can be done with a number of projectors working together to add intensities at the screen (with no registration problem).
   c. A practical means of achieving the multiple channels is to place an opaque mask with a number of holes in it over the projection lens
      1. Each can have its direction, color, optical path, intensity and aperture varied independently.
      2. Can allow user to "tune up" system by adjusting each bundle for best results at a given object.
   d. Some interesting effects are possible, ultimate value to the PI is unknown. Flicker can be used here as well.
4. Photochromic applications in non-coherent optical systems
   a. Primarily useful to realize masks, sharp or unsharp, positive or negative, from the input transparency.
   b. These masks can be viewed as a single transparency as well (with contrast manipulation, if desired).
   c. Optimum brightness efficiency calls for eyepiece viewing (deliver all photos to the user's eye).
5. Non-coherent systems are linear for intensity only, i.e. $I = \tau\, O$ where I is intensity at image place and τ is the transfer function. This is a severe limitation and leads one to coherent systems where both phase and amplitude can be controlled to provide great flexibility in image processing.

D. Image Processing with Coherent Optical Viewers

1. The Fraunhofer diffraction plane provides means for insertion of spatial filters

a. Essentially the optics of single slit diffraction experiment taught in freshman physics.
b. By moving object back from lens we obtain a real image at the image plane beyond the diffraction plane.
c. With this basic setup, we can engage in some fairly sophisticated spatial filtering operations.

2. The Fourier relationship between the object plane, diffraction plane and image plane
   a. Image can be represented mathematically as the product of the object and various transfer functions in the system.
   b. The variables are μ and ν , the two dimensional Fourier spatial transforms of the various components within the system.
   c. Since the optical analog of the time-frequency relationship in electronics exists, this system allows similar linear operations, but in space rather than in time.
3. Operations on the object transparency diffraction pattern are angularly related (quadrature) to the original detail.
   a. One dimensional operations can allow use of a slit source
   b. Two dimensional operations require a point source
4. Operations possible with fixed density masks.
   a. Low pass filtering.
   b. High pass filtering.
   c. Band pass filtering.
   d. Comb filters.
   e. Sine wave filters.
   f. Shifting functions.
5. Operations with photochromic masks for density control give dynamic capabilities to the user.
   a. Can rival TV in ease of control.
   b. Can provide some functions not realizable electrically.
   c. Phase control is more difficult.
6. Photochromic applications to coherent systems
   a. Photochromic operations at the object plane, such as dodging and unsharp masking, are still feasible.
   b. The operator can control the absorption at the diffraction plane in a dynamic fashion.
   c. Brightness feedback allows adaptation level to remain constant.

IV. GOALS OF IMAGE PROCESSING SYSTEMS

A. To provide interpreter with numerous enhancement capabilities for finding signal (pattern) in noise (background).

1. In a non-dynamic situation, the interpreter should at least be able to call out the change (in terms of how processed in the lab) to get a required result.

a. He should be able to call out a specific density range to be compressed or expanded.

b. Photochromic image processing allows this without much trial and error.

2. The more ideal case will allow the PI to interest with the image in terms of dynamic image operation. Flicker could be of special use here.

B. To allow interpreter to completely eliminate enhancement

1. Enhancement means distortion in most respects and after the initial contact and evaluation a more detailed study might well call for the non-enhanced image, except possibly for contrast correction. With an available means for contrast amplification at fine detail (no distortion), this would probably receive great use.

2. Negative enhancement, or overeliminating enhancement (image inversion) in a sense, should also be useful in certain situations.

C. The over-all goal, to optimize the system for visual inspection, means we must make use of every technique available, i.e., flicker, color, enhancement, suppression, pattern filters, etc. We feel photochromic coatings provide a means for achieving the desired effects.

Background References

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